Chapter 4

Multi-Objective Optimization of Two-Stage Thermo-Electric Cooler Using Differential Evolution:

MO Optimization of TEC Using DE

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ABSTRACT

In this chapter, the technical issues of two-stage TEC were discussed. After that, a new method of optimizing the dimension of TECs using differential evolution to maximize the cooling rate and coefficient of performance was proposed. A input current to hot side and cold side of and the number ratio between the hot stage and cold stage are searched the optima solutions. Thermal resistance is taken into consideration. The results of optimization obtained by using differential evolution were validated by comparing with those obtained by using genetic algorithm and show better performance in terms of stability, computational efficiency, robustness. This work revealed that differential evolution more stable than genetic algorithm and the Pareto front obtained from multi-objective optimization balances the important role between cooling rate and coefficient of performance.

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Table 1. Nomenclature

Symbol	Description
TEC	Thermo-electric cooler
TTEC	Two-stage thermo-electric cooler
DE	Differential evolution
GA	Genetic algorithm
SOO	Simgle-objective optimization
MOO	Multi-objective optimization
COP	Coefficient of performance
$Q_{c,c}$	Cooling rate at the cold side of colder stage

INTRODUCTION

TEC is solid state cooling devices. The operational principle of TEC is not similar to vapor-cycle based refrigerator, they use the Peltier effect through p-type and n-type semiconductor elements (Zhang, Mui, & Tarin, 2010). TEC is used to convert electrical energy into a temperature gradient. TEC uses no refrigerant and have no dynamic parts which make these devices highly reliable and require low maintenance. TEC generates no electrical or acoustical noise and are ecologically clean. TEC is compact in terms of size, light weight and have high precision in temperature control.

TEC can be a single-stage or multi-stages type. The commercially available single-stage TEC (STEC) (Figure 1) can yield a maximum temperature difference of about 60-70^oK when the hot side remains at room temperature (Huang, Wang, Cheng, & Lin, 2013). However, when a large temperature difference is required for some special applications, STEC will not be qualified. To enlarge the maximum temperature difference of TEC two-stage TEC (TTEC) (Figure 1) or multistage TEC can be used. Additional stage increases achievable but also leads to more power consumption and the reduction of efficiency of thermo-electric system (Wang, Wang, & Xu, 2014).

The application of TEC has been partitioned by their relatively low energy conversion efficiency and ability to dissipate only a limited amount of heat flux (Enescu & Virjoghe, 2014). Two parameters play a crucial role in characterization of TEC, one is cooling rate defined as the heat absorbed by the cold end of the TEC, the other one is coefficient of performance (COP) defined as the ratio of cooling capacity to electrical power consumed by the TEC. TEC operate at about 5-10% of Carnot cycle COP whereas compressor based refrigerators normally operates at more than 30% (Rowe, 2005). In TTEC, the cooling capacity, COP are related to the material properties of semiconductor, ratio number of semiconductor elements between the two stages and the applied current of each stage.

The main drawback of TEC is the poor COP and low cooling rate. They can be improved personally or simultaneously. From the parameters of the equation of TEC performance, we can group them into three categories which are specifications, material properties and design parameter (Rowe, 2005). The specification for TEC is the required temperature different and electric power consumption, the required value of cooling rate with or without satisfying respective COP. The specifications are usually provided by customers depending on the requirement of a particular application. The material parameters are restricted by currently materials and module fabricating technologies. Consequently, the main objective